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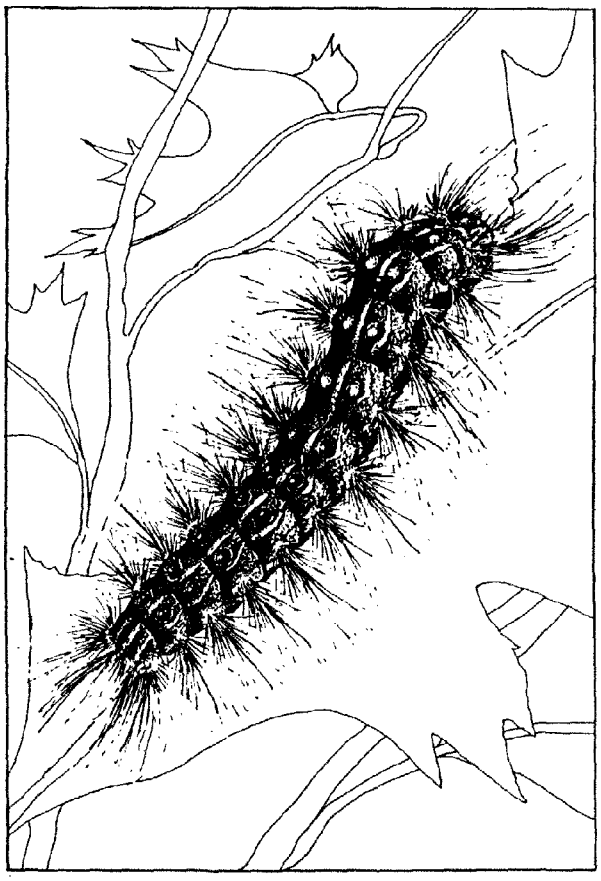
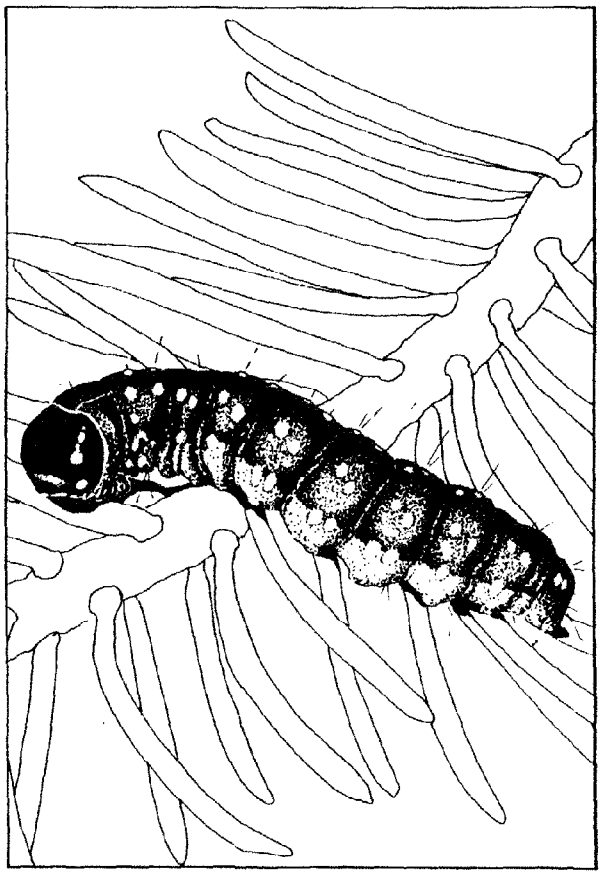
Proceedings

Forest Defoliator - Host Interactions: A Comparison between Gypsy Moth and Spruce Budworms





FOREWORD

The Canada/U.S. Spruce Budworms Program in cooperation with the Center for Biological Control of Northeastern Forest Insects and Diseases of the Northeastern Forest Experiment Station co-sponsored this Forest Defoliator-Host Interaction Workshop. This invitational workshop was limited to investigators of the spruce budworms and gypsy moth in the Forest Service, Canadian Forestry Service, and the University sector. The primary purpose of this workshop was to foster communication between researchers having a mutual interest and active research projects designed to understand the relationships between the host plant and forest defoliator feeding behavior, growth, and reproduction.

This Workshop was a follow-up to two previous meetings on host-insect interaction. In 1980, Dr. W. Mattson hosted a CANUSA-sponsored meeting at the North Central Forest Experiment Station, St. Paul, MN. This informal gathering brought together CANUSA Program investigators from the US and Canada for the purpose of sharing preliminary information and data on host-insect interactions. The second meeting took place in the fall of 1982. CANUSA(E) sponsored a Symposium on Spruce Budworm-Host Interaction at the Eastern Branch Meeting of the Entomological Society of America, Hartford, CT. The current Workshop developed from this Symposium. We found that participants were raising question concerning the similarity or differences between the spruce budworm and gypsy moth host interaction systems.

These Proceedings resulted from a three-day Workshop held in April 1983 at the Park Plaza Hotel, New Haven, CT. The structure of the Workshop allowed each participant a period for a presentation followed by lengthy discussion. These discussions were lively, friendly technical exchanges clarifying or elaborating on points raised by the speaker. Frequently, these exchanges were thought-provoking and often provided avenues for further detailed discussions and in some cases, future cooperative efforts.

The papers that make up these Proceedings were submitted at the Workshop as camera-ready copy. As a result, the participants did not have the benefit of reappraising their work in light of the discussions that followed their presentations or other ideas that developed at the Workshop.

Since the Workshop was planned late in the life of the CANUSA Program, we asked each investigator to be especially aware of the implications of these interactions on population dynamics of the insect in relation to forest management potential. When possible, we also asked that future research needs and direction be mentioned.

As technical coordinators for this Proceedings, it was our task to arrange and more effectively focus material so that papers provide a smooth transition of ideas and research activities on insect-host interactions for the spruce budworms and gypsy moth.

Lastly, we would like to acknowledge the support and confidence expressed by the following:

Denver P. Burns, Director, Northeastern Forest Experiment Station

Melvin E. McKnight, Program Leader, CANUSA

William E. Wallner, Director's Representative, Hamden, CT

August 1983 Robert L. Talerico, Broomall, PA

COVER SKETCH

Left, gypsy moth larva; right, spruce budworm larva.

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PROCEEDINGS,

forest defoliator--host interactions:

A comparison between gypsy moth and spruce budworms

New Haven, Connecticut, April 5-7, 1983

Technical Coordinators:

Robert L. Talerico
Research Coordinator
CANUSA(E)
Broomall, PA 19008

Michael Montgomery
Research Entomologist
Northeastern Forest Experiment Station
Center for Biological Control of
Northeastern Forest Insects & Diseases
Hamden, CT 06514

Sponsored jointly by the
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Northeastern Forest Experiment Station

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FOLIAGE CONSUMPTION BY 6TH-INSTAR SPRUCE BUDWORM LARVAE, CHORISTONEURA FUMIFERANA (CLEM.), FEEDING ON BALSAM FIR AND WHITE SPRUCE

A.W. Thomas

Research Scientist
Maritimes Forest Research Centre
Canadian Forestry Service
Fredericton, New Brunswick, Canada E3B 5P7

Female larvae ate about 1.5 times as much foliage as male larvae. Larvae ate significantly less old foliage than current foliage. Balsam fir current foliage was eaten in greater quantitities than any other foliage; white spruce current and balsam fir old were eaten to the same extent; very little old white spruce was eaten.

Introduction

To model the effect of budworm larval density on loss of fibre production in balsam fir and white spruce, data on the amount of current and old foliage consumed by larvae are required. This paper summarizes the work, to date, on the continuing study.

Materials and Methods

Field-collected branches of each host species were trimmed to the current year's growth attached to the apical 4 cm of the previous year's growth from which all needles had been removed. Other shoots were trimmed to 1-yr-old foliage attached to 4 cm of the previous year's growth. About 250 such shoots were prepared from any one tree at any one time. Each shoot was placed in water overnight. The following day, surface water was removed from the stem and the shoot was weighed. Shoots that had wilted overnight were discarded. Each shoot was placed in a numbered screen-topped cup with the base of the shoot projecting through a hole in the bottom of the cup and into water. One newly-moulted, i.e., less than 8 h old, unfed 6th-instar larva was placed in each cup with one shoot. Approximately 100 males and 100 females were used for each experiment. The remaining 50 shoots were used to construct a standard curve relating foliage dry weight to fresh weight. These shoots were oven-dried at 65°C when 50% of the larvae had pupated. The standard curve was used for predictive purposes.

The experiments were carried out in a room at 26°C, 80% RH, and a 16 h photoperiod. As each larva pupated, the pupa was placed in a glass vial and the shoot was oven-dried.

The dry weight of the shoot offered to each larva was predicted from a regression of dry weight on fresh weight, i.e., from the standard curve. The ovendry weight of the shoot at the end of the larval feeding period was subtracted from the predicted original dry weight. The difference in dry weights was an estimate of the amount eaten.

The frass produced by each 6th-instar larva was oven-dried and weighed. After 24 h, emerged moths were killed, oven-dried, and weighed.

Results and Discussion

Standard Curves

The correlation coefficient between dry weight and fresh weight of foliage was very high for both current and old foliage; 10 standard curves for balsam fir ranged between 0.903 and 0.997 and averaged 0.977; 6 curves for white spruce ranged between 0.972 and 0.999, averaging 0.990. However, the standard errors and consequently the 95% prediction limits about the mean of a new sample were too high for the dry weight of a single shoot, or even small samples, to be predicted with sufficient accuracy. For example, the standard errors, for different sample sizes, of predicted mean dry weight for balsam fir current year foliage having a mean fresh weight of 3.64 g were obtained from the following regression

Dry weight (mg) = 31.06 + 308.41 fresh weight (g)
$r = 0.99$, $n = 51$, $Sy.x = 4683.9$

Sample size	Standard error, mg
5	32.6
10	24.4
20	19.0
40	15.7
80	13.7

Because the proportion of water present in current year shoots drops continuously during the growing season, a standard curve had to be developed for each experiment. When 6th-instar larvae first appear in the field, the water content of the current year shoots is 80-85%, by the end of the growing season it is 55%, and in 1-yr-old foliage water content is 49%.

Foliage Consumption

The data from four experiments using balsam fir current year foliage were pooled, and similar data from four experiments using balsam fir old foliage were pooled. The average amount of current foliage consumed by a 6th-instar female larva ($n = 203$) was 315 mg dry weight, for males it was 207 mg ($n = 174$). For old foliage the average figures were 201 mg ($n = 95$ females) and 128 mg ($n = 139$ males). This reduction in

consumption associated with old foliage affected both males and females to the same extent, about 38%. Females ate 1.52 as much current foliage and 1.57 as much old foliage as did males.

The above statistics refer to larvae that eventually emerged as moths. During the study, some pupae died. Females that died in the pupal stage consumed an average of only 211 mg of current fir foliage whilst males consumed an average of 132 mg.

The data from three experiments using white spruce current year foliage were pooled, and similar data from four experiments using white spruce old foliage were pooled. The average amount of current foliage consumed by a 6th-instar female larva (n = 152) was 190 mg dry weight, for males it was 134 mg (n = 122). For old foliage the average figures were 92 mg (n = 108 females) and 67 mg (n = 83 males). As with balsam fir, the reduction in consumption associated with old white spruce affected both males and females to the same extent. However, this reduction in consumption of white spruce, 51%, was greater than the 38% reduction associated with old fir. Females ate 1.42 as much white spruce current foliage and 1.37 as much old foliage as did males.

Females dying as pupae ate, on average, 156 mg of white spruce current foliage whilst males ate 125 mg.

Both male and female 6th-instar larvae eat significantly more balsam fir than white spruce, a difference that holds true for both current and old foliage. As white spruce produces more foliage than balsam fir, the net effect is less defoliation on white spruce, and presumably less fibre loss, if there is approximately the same density of larvae on each tree.

Tree Species and Insect "Performance"

The dry weight of a 24-h-old moth is a convenient measure of an insect's performance. White spruce current year foliage produced the largest moths, males averaged 11.6 mg, females averaged 21.1 mg; followed by balsam fir current year foliage, males 8.2 mg, females 15.3 mg. Balsam fir old foliage produced males which averaged 7.3 mg and females which averaged 11.6 mg. White spruce old foliage gave rise to very small moths; males averaged 2.9 mg and females averaged 4.7 mg.

White spruce current foliage also proved to be the most efficient diet in the sense that the ratio, dry weight of needles eaten:dry weight of moth, was lower than for any other foliage, i.e., 12:1 for males, 9:1 for females. The other foliages were relatively inefficient. Balsam fir old foliage although producing smaller moths than balsam fir current foliage was the next most favorable diet in that the ratios for both males and females were 17:1. Balsam fir current foliage had a ratio of 25:1 for males and 21:1 for females. White spruce old foliage ratios were 23:1 for males and 20:1 for females.

Because of the problem, with this method, of obtaining sufficient accuracy of the amount eaten, I have been able to deal only with means. For a better understanding of the system it is preferable to use data from individual insects, or trends. An indirect way of looking at consumption is to consider frass production. This has the distinct advantage that the amount of frass produced can be measured without error. It is also reasonable to assume that frass production is representative of the amount eaten. Thus, another way of comparing insect performance on the two hosts is to compare the relationship between moth weight and frass produced by 6th-instar larvae.

Dry frass weight and dry moth weight were correlated and regressions, for comparative purposes, could be defined. For young current shoots of white spruce, collected 31 May 1982, containing 83% water, the regression of frass produced by 6th-instar female larvae on subsequent moth dry weight was

Frass (mg) = 39.37 + 5.010 moth weight (mg)
$r = 0.82$, $n = 101$, $Sy.x = 401.79$

For similar shoots from the same tree, but collected 15 days later, and containing 71% water, the regression was

Frass (mg) = 39.09 + 8.965 moth weight (mg)
$r = 0.79$, $n = 17$, $Sy.x = 114.43$

Young current white spruce was the preferred diet in that it produced a moth of a given weight more efficiently than slightly older current foliage, e.g., a female of dry weight 15 mg would have produced 114 mg of frass as a 6th-instar larva feeding on young current shoots, but two weeks later would have produced 174 mg of frass. On average, the ratio of frass weight:moth weight was 6.8:1 for young current foliage and 13.1:1 for older current foliage. A similar trend was seen with males and for both sexes feeding on young and older current year balsam fir needles.

These data confirm the earlier conclusion that current foliage is a preferred diet and they also suggest that such foliage rapidly looses quality. The scenario envisaged for white spruce is that the youngest foliage of the current year is the preferred food, relatively small amounts are required to produce a moth of a certain size; as the foliage ages its suitability as a food declines, it is still readily palatable but more of it is required to produce a moth of a certain size; as it ages still further, it becomes unpalatable and larvae eat very little of it.